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EXPERIMENTAL STUDIES ON A GAS DYNAMIC LASER WITH NARROW THROAT AND HIGH AREA-RATIO GRID NOZZLES

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Experimental Studies on a Gas Dynamic Laser With Narrow Throat and High Area-Ratio Grid Nozzles

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[1] Manuscript received in June, 1981.

Abstract This paper describes a combustion-driven CO_2 gasdynamic laser with a throat height of 0.3mm and an area-ratio 30 grid nozzles, and presents some experimental results. The behavior of flow and the location of shock waves in the optical cavity were observed. The variation in small-signal gain G_o with CO_2 or H_2O contents were measured and compared with the experimental data from similar equipment of nozzle throat height 0.8mm and area-ratio 17. Some advantages are obvious for the narrower throat height and higher area-ratio GDL, i.e. the G_o can be increased by a factor of 50% and the H_2O contents may be increased from 1% to 5%.

I. Introduction

Shortly after the first gasdynamic laser was reported by E. T. Gerry[1] the suggestion for the "second generation" gasdynamic laser technology was proposed by J. D. Anderson et al,[2] and smaller throat height, larger area-ratio, higher gas stagnant temperature and pressure, and higher moisture content were suggested. Calculation had shown that with these combinations,

higher gain coefficient and higher usable energy were achievable. Simulation test was later carried out by J. S. Vamos in sudden wave wind tunnel.[3] However, no similar results were published for combustion driven gasdynamic laser devices.

Based on the result of combustion driven CO_2 gasdynamic laser with nozzle throat height 0.8mm and outlet area-ratio 17, the characteristics of arrayed gasdynamic laser with nozzle throat height 0.3mm, area-ratio 30, and flow rate 11/sec was studied. This paper describes the measurement of small signal gain and the comparison with similar data obtained on a throat height 0.8mm and area ratio 17 device.

II. Experimental Set-Up

As shown in figure 1, the combustion chamber was a cylinder 140mm in inner radius and 400mm in length and the mixing section was 350mm in length, both were layered structure. The combustion agent was a mixture of CO and H_2, and air was the combustion-assisting agent. CO_2 and H_2O, generated by combustion process, were mixed with N_2 to reach certain pressure and temperature. Particle number inversion was achieved by virtue of difference in delay speed of CO_2 energy levels through rapid expansion when particle stream passed by the supersonic nozzle.

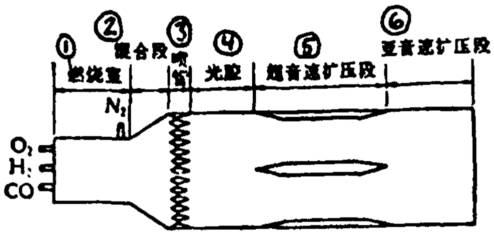

Figure 1: Illustration of combustion-driven gasdynamic laser

Key: 1 - combustion chamber; 2 - mixing section; 3 - nozzle; 4 - light cavity; 5 - supersonic expansion section; 6 - subsonic expansion section.

To better "freeze" the high energy CO_2 and N_2 particles,the nozzle throat height was chosen to be 0.3mm, the ratio of nozzle outlet to throat area was chosen to be 30, the ratio of specific heat of gas mixture was chosen to be 1.37. Design of nozzle wall was based on the analytic method,[4] and the structure was an arrayed combination with 32 blades mounted on the panel to form a nozzle cross section of 300mm wide and 30mm high. To prevent formation of sudden wave at the joint of nozzle and light chamber and deterioration of quality of laser beam, the top and bottom walls of the light chamber and nozzle panel were molded into a single body. Also, proper expansion was made to correct the effect of the boundary layers.

The light chamber was 170mm in length. Circular or rectangular mirrors could be mounted on the sides to form optical resonant chamber. The mirrors were coated with oxygen-free copper plated gold film.

The pressure expansion section was divided into the supersonic and subsonic sections. Movable flow-guiding plates

could be added to the center of supersonic section to adjust the cross-sectional area of the second throat. The subsonic section resumed the pressure to atmospheric pressure.

III. Small Signal Gain

Small signal gain, a measure of CO_2 particle number inversion, is an important parameter when the performance of a laser device is concerned. Through the measurement of this parameter, the optimal working condition can be obtained and the design of the optical resonance chamber can be based. Magnification method was used in this study to measure this parameter.[5]

The principle of the magnification method was to penetrate a laser beam of equal wavelength through the excited media and observe the increase in its intensity and calculate the gain of the media. As shown in figure 2, let I_o and I be the intensities at the inlet and outlet, respectively, and the distance between H_1 and H_2 be L, the average gain along this distance is $G_o=1/L \ln(I/I_o)$.

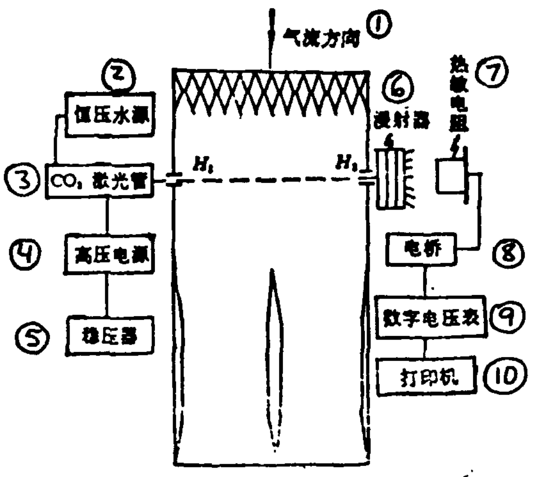

Figure 2: Illustration of measurement of gain

Key: 1 - direction of gas flow; 2 - constant-pressure water supply; 3 - CO_2 laser tube; 4 - high voltage power supply; 5 - voltage stabilizer; 6 - scattering device; 7 - heat-sensitive resistor; 8 - electrical bridge; 9 - digital voltmeter; 10 - printer

The experimental result (measured at 26mm downstream of nozzle outlet) is summarized below.

1. Variation of G_o with CO_2 content

If the moisture content is kept constant (around 2.5%) and the CO_2 mole fraction varied, the best condition was achieved when CO_2 content was around 13 to 14%. In this range, the average gain G_o was 0.85/meter (see figure 3) and the maximum G_o was 0.96.

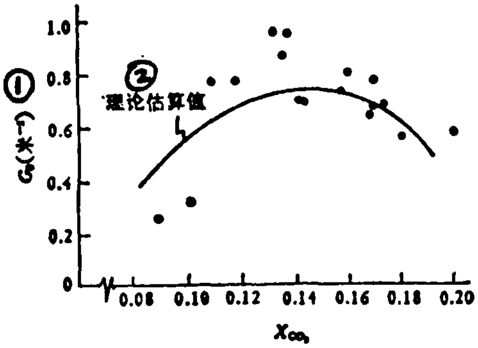

Figure 3. Variation of Go with CO2 mole fraction

$h^* = 0.3mm$ $A/A^* = 30$
$X_{H_2O} \doteq 0.025$ $P_0 \doteq 50atm$

Key: 1 - m^{-1}; 2 - theoretical value

From the two sets of data mentioned above, the small signal gain for narrow throat, large area-ratio gasdynamic laser was increased by about 50%.

On the similar device with nozzle throat height 0.8mm and area-ratio 17, the best G_o was also obtained around CO_2 molar fraction of 13%. However, the average gain was 0.58/meter (see figure 4) and the maximum gain was 0.69.

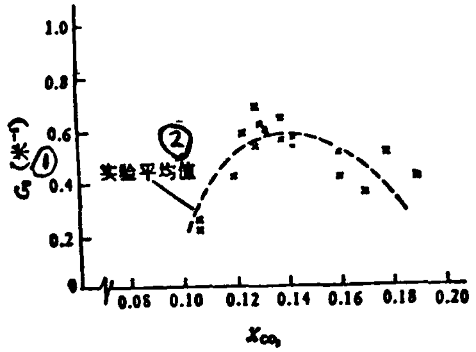

Figure 4: Variation of G_o with CO_2 mole fraction

$h^* = 0.8mm$ $A/A^* = 17$
$X_{H_2O} \doteq 0.008$ $P_0 \doteq 22atm$

Key: 1 - m^{-1}; 2 - experimental average value

2. Variation of G_o with H_2O content

Maintaining CO_2 content to be within 12 to 14% and adjusting H_2 input to change the H_2O percentage after combustion, the variation of small signal gain G_o with H_2O molar fraction was measured and shown in figure 5. When H_2O content was 2.5%, the average G_o was 0.85(1/meter); when H_2O content was 5.6%, the average G_o was 0.51(1/meter). For gas laser with nozzle throat height 0.8mm, the best condition was achieved when moisture content was around 0.8%. When moisture content exceeded 5.5%, G_o would approach 0 (figure 6). This explains why gasdynamic laser with narrower throat and larger area-ratio could allow more moisture content.

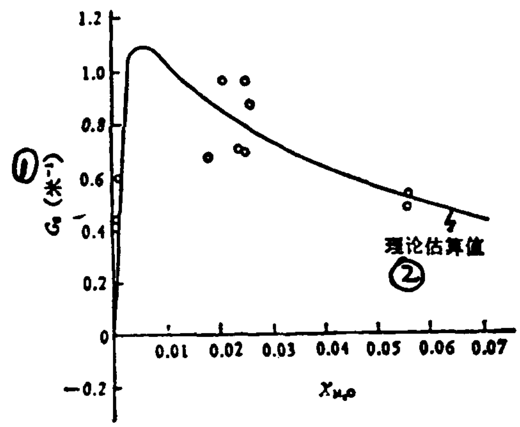

Figure 5: Variation of G_o with H_2O mole fraction

$h^* = 0.3mm$ $A/A^* = 30$

$X_{CO_2} \doteq 0.13$ $P_0 \doteq 50atm$

Key: 1 - m^{-1}; 2 - theoretical value

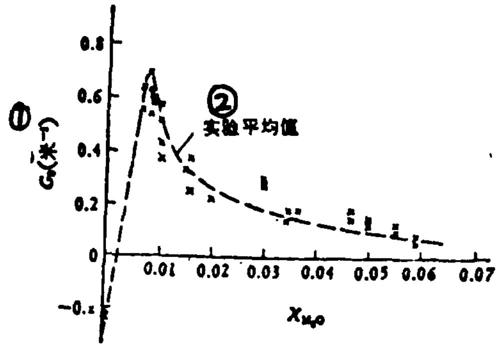

Figure 6: Variation of G_o with H_2O mole fraction

$h^* = 0.8mm$ $A/A^* = 17$

$X_{CO_2} \doteq 0.13$ $P_0 \doteq 22atm$

Key: 1 - m^{-1}; 2 - experimental average value

3. Variation of G_o with stagnant temperature T_o

If the working medium in the combustion CO_2 gasdynamic laser were not pre-heated, the elevation in temperature was mainly achieved by increasing the input of CO or H_2, thus increasing the CO_2 or H_2O after combustion. When the moisture content was fixed, the temperature was directly determined by the amount of CO_2. Therefore, the relationship between G_o and T_o is the same as that between G_o and CO_2 (see figure 7). When T_o was 1500 to 1600K, small signal gain G_o reached its maximum. When T_o exceeded 1600K, G_o would start decreasing because CO_2 content would be driven from the optimal working range, energy exchange between N_2 and CO_2 would be affected, and rate of agglomeration of low energy CO_2 molecules would increase.

Based on the experimental conditions specified in figures 3, 5, and 7, the variation of G_o with respect to CO_2, H_2O and T_o was calculated with normal procedures and was basically consistent with the experimental result.[6]

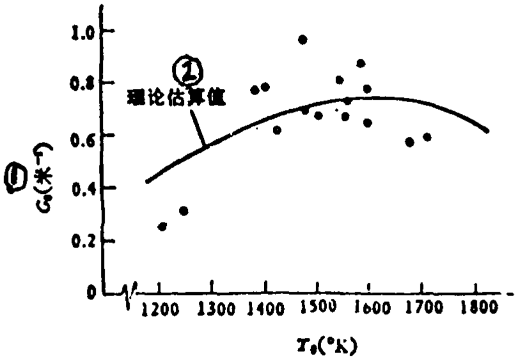

Figure 7: Variation of G_0 with stagnant temperature T_0

$h^* = 0.3mm$ $A/A^* = 30$
$X_{H_2O} \doteq 0.025$ $P_0 \doteq 50atm$

Key: 1 - m^{-1}; 2 - theoretical value

IV. Conclusions

1. The small signal gain was increased by 50% on gasdynamic laser with nozzle throat height 0.3mm and area-ratio 30 than the similar device with nozzle throat height 0.8mm and area-ratio 17.

2. With the decrease in nozzle throat height, increase in area-ratio, and increase in stagnant temperature and pressure, moisture content in the working gas could be increased from 1% to 5%, thus providing a possibility for using combustion gas with higher hydrogen content. (While high-hydrogen gas generates higher temperature, the moisture content after combustion was also higher.)

3. For gasdynamic laser devices with narrower throat, the effect of nozzle manufacturing on the optical chamber flow field was significant and high accuracy is required. Also, effective cooling procedure should be taken to prevent deformation of nozzle as a result of heat during experiment and deterioration of optical beam quality.

Referen-es

[1] Gerry, E. T.: Gasdymanic Laser, AIAA paper, 9, 71-23 (1971)

[2] Anderson, J. D., Harris, E. L.: Modern Advances in the Physics of Gasdynamic Lasers, AIAA paper, 10, 72-143 (1972)

[3] Vamos, J. S.: Small Signal Gain Measurements in a High Area-Ratio Nozzle Shock Tunnel, GDL, AIAA paper, 12, 74-177 (1974)

[4] Yu, G., Wu, C. B.: Study of Gasdynamic Laser with Arrayed Nozzles, Laser, 7, 9, (1980)

[5] Chen, G. I., Li, G. C.: Measurement of Small Signal Gain of CO_2 Gasdynamic Lasers, Research Report, Institute of Mechanics, Academia Sinica, China, (1980)

[6] Chen L. E., Chu, T. C.: Calculation of Gain and Flow Parameters of Gasdynamic Laser Devices with Normal Calculation Methods, Research Report, Institute of Mechanics, Academia Sinica, China, (1980)

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